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OCEANUS

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The romantic aspects of fish nets and fishing boats form an unresisting lure for artists and for almost everyone of us. Yet, few occupations are less romantic to their practitioners. Commercial fishing is arduous work, the hours are long, the work hard, living space is cramped and all too often a boat does not return from the banks. Indeed, the old saying: 'Fish is paid for dearly,' does not refer to the price on the market shelf but to the cost of an untold number of fishermen who never came back to port.

As if fighting the sea is not enough, the fisherman also has to contend with an uncertain supply. He is not a harvester, but a hunter. It is a source of satisfaction that through the efforts of Senators Leverett Saltonstall and John F. Kennedy, funds have been made available to lighten the fisherman's toil by removing some of the uncertainties attached to his occupation.

According to Dr. R. V. Truit of the Chesapeake Biological Laboratory, the world's annual catch from the sea is equivalent, pound for pound, to about seven and a half billion broiled chickens or some 37,000,000 steers, certainly a significant contribution to the food supply. There is disagreement among scientists whether this represents all that can be taken from the sea or that the catch can be increased manyfold. More research on the productivity of the sea, on the influence of the environment on fish populations, exploratory fishing and improvement of vessels and gear will be needed to provide the answer.

Si pars oceani movetur, totus oceanus movetur.

For many years, many people in many countries have studied the movements of the sea but it is a bold man indeed who would state that we know even the general circulation of the oceans with any kind of precision.

Fishery biologists have been perplexed for an equal number of years by the question: "How does the movement of the sea influence the fish population?" That it hardly can fail to do so is equally agreed, either the fish are moved, their food is moved or the eggs and spawn are moved. A better understanding of the movements of the sea and the overlying atmosphere will lead to a better understanding of the great fluctuations which from time to time plague the fishing industry.

In this and the next issue of OCEANUS we present the views of some fishery biologists and hydrographers and take this opportunity to welcome others to space in our columns, to contribute their opinions on this important and difficult subject.

Sword! Sword!

Probably the smallest swordfish ever taken north of Florida, this 16 inches long specimen was caught by Captain Scott Bray and biologist Richard H. Backus while fishing with a dipnet and a light over the side of the ATLANTIS at 38° 25′ North and 69° 10′ West.

The fish showed up as an intense bright blue streak when it entered the light cone. Weighing about one half pound the small sword is of great interest as it is in the midst of a remarkable transformation. The long lower jaw will disappear, the very rough skin will smoothen and the long dorsal fin, now reaching along the entire back will turn into its characteristic shape that causes the yell: "Sword! Sword!" from the mastheads of swordfish boats.

During the same cruise many individuals of a cousin of the snake mackerel, also formerly a "rare" fish, were taken by the same method. Only eight specimen of *Nealotus tripes* were known to have been taken in widely separated regions in the oceans since 1865, when the fish was first described. About six inches long, one of the beautiful looking fish grabbed Backus by the finger and exercised its saber tiger type teeth. The catch and sighting of many more of these fishes is but one more example that rare fishes may not be so rare if one looks hard and long enough.

INVESTIGATION OF CLIMATIC AND OCEANOGRAPHIC FACTORS INFLUENCING THE ENVIRONMENT OF FISH

BY DEAN F. BUMPUS

The above title identifies the contract which the Institution has with the U. S. Fish and Wildlife Service under the Saltonstall-Kennedy Act. The contract will run for three years, commencing last July and will be financed to the extent of $200,000.

The questions started popping as soon as we proposed the contract. What did we plan to do? Had not capable scientists been working on this problem from the very beginning of fishery investigations? How could we be so bold as to suggest we could solve these problems now in three years?

We do not expect to solve the great fisheries problems in three years, but we do expect to make some definite steps along the road using several approaches, some old, some new. We hope to be successful enough to warrant continuation of the project and thus accomplish the ultimate solution of some problems, one by one.

The general problem is: Why does the abundance and distribution of the great populations of fish change from time to time? To what extent are these changes related to shifts in oceanic circulation and what climatic influences bring about these shifts?

How are we going to go about it? Firstly — we shall set up a series of oceanographic observation posts at each of eleven lightships along our eastern seaboard. This part of the program will be with the full cooperation of the U.S. Coast Guard. The purpose will be to monitor the day to day and week to week changes in the temperature regime along the coast. Heretofore we have been dependent on the temperature and density measurements at docksides, measurements made for the most part by the U. S. Coast and Geodetic Survey at their tide stations. The oceanographic observation posts will move the frontier of daily measurements to between the 10 and 25 fathom contours. Daily measurements of temperature with the bathythermograph, daily surface salinity and weekly bottom salinity measurements will be made at the following lightships: Portland, Boston, Nantucket, Ambrose, Barnegat, Five Fathom, Winter Quarter, Chesapeake, Diamond Shoals, Frying Pan Shoals, and Savannah.

We hope to set up the same system on each of the "Texas Towers" when they are taken over by the Air Force from the builders.

Secondly — we have an extensive collection of records of the distribution of temperature and salinity across the continental shelf south of Woods Hole. This collection of data extends back

to the founding of the Oceanographic Institution and beyond. Since 1941 there has accumulated an especially valuable collection of bathythermograph records which will enable us to define carefully the cycle of temperature over the shelf and to note departures from the regular cycle. We shall then try to understand the reason for these departures by a thorough examination of the historical weather records, the air temperature, rainfall, stream flow, wind, storms, etc. Through collaboration with our friends down the street at the "Fisheries Station" we shall investigate the effect, if any, of these seasonal departures on the fisheries.

Thirdly — we shall make a very detailed examination of the waters south of New England from time to time in order to gain a better understanding of the mixing processes, the rate of exchange of fresh water across the continental shelf, the contrary penetration of salt across the shelf, the distribution of certain nutrient chemical constituents and certain optical properties of the water. By this multiplicity of measurements we hope to identify water types and sources and follow the movement of water along and across the shelf.

Fourthly — in order to monitor changes in temperature at strategic points on the shelf we shall place recovery buoys* capable of measuring and recording temperature for a period of several months. These buoys will be anchored to the bottom and located at any desired height above the bottom. Each will be recovered by the dropping of a small explosive charge in its vicinity whereupon it will release its anchor and bob to the surface and be recovered.

*Oceanus II, 2. "New Instruments"

Drawing a Temperature Profile On Board Atlantis.

Fifthly — to gain a better understanding of the non-tidal drift we shall place a string of about 20-ft. long, radio equipped drift bottles across the shelf and monitor their position from time to time by flying out over the shelf in our PBY, calling each buoy in sequence, whereupon it will reply and we shall home on the radio transmission.

There, in a few words, is the program we have cut out for ouselves. There are many more problems to tackle before we can explain why fish populations migrate as they do, why they are found in certain places and not others, and why they appear at certain places at certain times and not at other times.

One more remark and I have finished for now. We have been asked why we are working south of New England where the fishery is not especially valuable when Georges Bank, one of the most productive marine areas in the world, is almost as close to Woods Hole. We know that the problem we have undertaken is a difficult one. We are certain that the hydrography of Georges Bank is much more complex than that of the shelf south of New England. We have much more information already at hand on the area south of Woods Hole which we think will contribute materially to the understanding of the problem in that area. With the dynamics of the simpler but by no means uncomplicated area understood we shall be ready to tackle the next more difficult one.

ABOUT THE AUTHOR

Oceanographer Dean F. Bumpus has been with the Institution since 1937 and has been most active in the study of inshore water masses. His latest papers deal with the hydrography and the distribution of organisms over the continental shelf south of Cape Hatteras and are valuable contributions to the understanding of complex inshore circulations.

Woods Hole Recovery Buoy.

Solving The Fundy Herring Puzzle

By Archibald G. Huntsman

One of the few examples known how the environment influences a fish population.

Among fishes, herring are outstanding for the density and immensity of their schools, which maintain large fisheries on both sides of the North Atlantic. Why should the behaviour of such common fish be so puzzling? May it not be because we misinterpret their behaviour?

In the Passamaquoddy region of the outer part of the Bay of Fundy, where Maine and New Brunswick meet, herring are particularly abundant. They can frequently be seen in the water, and they are captured in all months of the year. The fishermen there should know pretty well how these fish behave. One of the fishermen's sayings is: 'In dry weather herring go to fresh water to get a drink.' They base this upon observed facts. But whether or not they are right that the fish swim riverward to relieve their thirst, who knows?

In this region, herring are largely taken in fixed traps or weirs, constructed of stakes surmounted either by brush or by poles which support netting. With a tidal rise and fall of as much as 28 feet, the walls must stretch from below low water to the surface at high water. The men who tend these weirs can well see what the herring do. In the centre of the region are two neighboring weirs where two very different aspects of herring behaviour can be witnessed. One weir blocks the mouth of the small Doctor Cove, which empties and fills with the tide. The owner states that the trapped herring, which are free to move anywhere in the comparatively still and deep water of the cove at high tide, tend to be seen near the mouth of a small brook that empties into the Cove on its west side. This is not a matter of dry weather. That the fish are near the brook mouth has a simple explanation, one that is very different from thirst. The surface outflow of fresh water from the brook entrains the salt water, which is replaced by a slow subsurface movement toward the mouth of the brook. It is this movement of the water rather than their own exertions that takes the small herring thither, since they are not far below the surface.

The neighboring weir, known as the Black Prince, is related, not to a cove, but to a bar that juts out from the shore. A rather strong tidal current flows most of the time in one direction over and past this bar. The weir is built against the shore on the side of the bar from which the current comes, with its mouth at the bar. Herring that are being swept past the weir and the bar, tend to collect in the eddy behind the latter, which the owner of the weir can verify by getting them to rise to the surface with a light at night. When the current slackens sufficiently, the herring rise from this deep

eddy to stem the current over the bar and into the weir. All this is very simple behaviour. The fish are first carried along in a strong current, then they remain stationary in the weaker current of an eddy, and finally, when this becomes quite weak, they head and swim upstream close to the bottom. There is no evidence that they orient in relation to the bottom except when close to it. Away from it, they swim variously and are transported by the current, which on the whole determines where they will be found.

Passamaquoddy Bay, which gives its name to this region, is fifteen miles long, six miles broad and about twenty fathoms deep. Small herring are taken in the many weirs along its shores. Two substantial rivers discharge fresh water into the Bay at or near its head, and this is mixed with sea water in their estuaries before it reaches the open Bay where it forms a thick and relatively light surface layer. With heavy freshets, capture of herring ceases all around the Bay; but, as the freshets subside, capture is resumed in greater volume than ever, starting at the mouth and shifting inward during a period of a week or so to the estuaries at the head. This indicates that the fish are carried outward with great outward flow, but back inward as the outflow thins and the return current approaches the surface.

Transport by Current

Indeed, the character of the distribution of herring throughout the whole Bay of Fundy reveals their dependence upon transport by currents. This kind of fish is confined to sea water and to the temperate zone, which reflects inability to endure either fresh water or extremes of temperature. In the Bay of Fundy, both salinity and temperature are suitable, yet these fish become less and less abundant going inwards. This seems to be a matter of food, since conditions are very poor for the growth of the microscopic floating plants, such as diatoms, that serve as food for the floating crustaceans, such as copepods, that in their turn serve as food for herring. The high tides engendered in these narrowing and shallowing waters give strong currents that mix the water rather steadily and thoroughly. This does two things. It makes the water more or less turbid with silt from the bottom so that only a thin surface layer is well lighted, and it carries floating plants up and down so that few remain steadily enough in that thin layer to get sufficient light for growth. This repression of plant growth that prevents production of food for herring varies in degree throughout the Bay and its tributary tidal waters. The variety remains to be worked out, but it can be recognized to some extent in the varying abundance of the floating copepods that depend upon these plants for food. The copepods are least abundant where the water is deepest as well as most turbulent and turbid, that is, where conditions are poorest for plant growth.

The Bay of Fundy, which with its branches extends inland for 190 miles, is remarkably poor as a producer of food for herring. Although little of the sig-

"Rolling" the Sardines in a Dip Net from the Seine into a Boat inside the Weir.

Photo: Canadian National Film Board.

nificant research has yet been done, this is quite evident. Nevertheless, herring are taken in it everywhere for 150 miles inland from its mouth.

Fish Catches

Early in the 19th century, the use of weirs for capture of fish spread from the Nova Scotian side of Fundy to the Passamaquoddy region. These weirs took herring of all sizes, and the small ones were at first used only to a limited extent, for bait and manure. In 1865, they began to be pressed for the oil they yielded, and in 1876, to be canned as sardines. Full development of the sardine industry took about 25 years. Several hundred weirs were erected throughout the region to make available the many small herring there. The course of the fishery shows that intensive removal of the small, immature herring greatly reduced the numbers of spawners just outside Grand Manan and perhaps in more distant waters. It also at first increased and then decreased the numbers of medium herring taken in the outer part of the region for preservation by smoking. There were indications that the very large yearly total catch, which was easily twice as great in weight as any of the catches of earlier years, represented an increase in the numbers of small herring. Reduction in numbers of the larger fish might well have made more food available for the smaller ones. With rather marked fluctuations, the general high level in the catch has now been maintained for over fifty years by intensive fishing for the sardines, which continue in great demand. In fact, the waters of Charlotte County, N. B., yielded in 1946 and 1947 more herring (over 100,000,000 pounds each year) than had ever been recorded previously.

The real puzzle is: Why are so many small herring concentrated throughout the year in the Passamaquoddy region where the adults do not spawn and also where local production of food for them is very slight? Both the small herring and their food must come from the Gulf of Maine through the Bay of Fundy into the region. The solution of the puzzle must lie in the water circulation that transports the herring larvae and their food. Only fully developed larvae are seen in the region. Fully developed herring larvae, although

for the most part transparent, have black pigment covering their eyeballs, which are, therefore, decidedly conspicuous and give these fish the name of "eyeballs." Only at this stage do they begin forming into schools and keeping near the surface, as is evident by their approaching shore and entering weirs.

The circulation that brings such surface forms to the Bay from the Gulf of Maine is largely due to fresh water from the Saint John River, which drains 21,500 square miles of land in New Brunswick, Maine and Quebec, and which discharges into the Bay of Fundy, about midway in its length, over two-thirds of all the fresh water reaching that Bay. This great discharge is mixed with twice its volume of sea water in the Reversing Falls before it issues from Saint John harbour. Sea water for the mixing comes from the Gulf of Maine along the Nova Scotian shore and across the Bay of Fundy. The mixture passes southwestward along the New Brunswick shore to the Passamaquoddy region. While water leaves Passamaquoddy Bay through the Western Passage, there is a predominance of inward movement through the eastern Letite Passage. Along this course the "eyeballs," as well as surface copepods such as *Acartia clausi*, which serve them for food, will reach Passamaquoddy Bay from other parts of the Bay of Fundy, from the Gulf of Maine, and even from more distant waters.

The circulation that holds such surface forms in Passamaquoddy Bay is due to rather great discharge from rivers at the head of the Bay and to strong tidal mixing, along the shores, of the light surface water, which the river estuaries furnish to the

Removing Sardines from the Hold with a Tub that Measures the Catch at the Factory.

Photo — Canadian National Film Board.

Bay, with the heavier and now deep water that has entered through Letite Passage. The surface water carries surface forms toward the shores of the Bay. The water mixed along the shore moves at intermediate depths toward the mouth of the Bay and thus fails to carry away either the surface forms or the deep forms that have been brought in. In this way the small herring and their food, whether surface forms or deep forms, are held in the Bay and concentrated together near the mixing places for easy feeding.

A Natural Trap

Passamaquoddy Bay is an extraordinarily effective mechanism for concentrating the smaller herring with their food to produce small sardines from herring larvae during the season from June to October. This mechanism was particularly effective in 1951, and the explanation would seem to be that the Saint John discharge was over twice as great as usual in July when "eyeballs" enter the Bay and that there were no heavy freshets into the Bay during the summer to carry the brit (herring between "eyeballs" and sardines) out. The exceptional effectiveness of the mechanism became evident in early August when the surface of Passamaquoddy Bay was seen to be peppered generally with the excreta of the brit. When a west wind blew for some time, the excreta accumulated in windrows on the beach at Letite. This unexampled phenomenon showed that there were in the Bay immense quantities both of the brit and of their food. Phenomenal production of sardines was clearly demonstrated by capture in weirs along the Canadian shores, the major portion of the Bay, from September to December inclusive, of 22,214,900 pounds of the small sardines.

There has been great complaint of scarcity of sardines this past spring and summer. Last fall only 1,015,000 pounds of the small ones were taken in the Canadian part of the Bay, the lowest amount for many years. There was high Saint John water to bring in the "eyeballs" in 1954, but there were floods through the Bay three to four times as heavy as in any summer for many years to carry the brit out.

Only a slight beginning has been made in this way in attempts to solve the puzzle of where the herring will be found, and in what quantities and sizes. Only knowledge of the environment, that is, of the oceanography, will provide the solution.

ABOUT THE AUTHOR

Dr. Archibald C. Huntsman, Consulting Director, Fisheries Research Board of Canada and Professor of Marine Biology at the University of Toronto. Dr. Huntsman has been connected with the Institution almost since its founding and served as a Trustee for many years. He has devoted much of his time in an advisory capacity to this Institution.

Associates News

The Open House held for the Associates of the Woods Hole Oceanographic Institution on August 8, was considered a great success. In practically every room in both buildings, members of the scientific staff and their assistants were busy explaining their work with the aid of specially prepared charts and by the exhibition of some of the modern instruments developed here. Invitations to the Open House had also been extended to members of the New York Yacht Club, who were visiting Woods Hole that day on their summer cruise, and to members of local yacht clubs. Many of the latter appeared but it is to be regretted that the New York fleet arrived too late on anchorage, so that but few members were able to visit the laboratories.

In the afternoon your Executive Committee met in the Director's room and received the Annual Report of the President Mr. Gerard Swope, Jr.

The resignation of Mr. Gerard Swope, Jr., as President of the Associates, was accepted with extreme regret. It was voted that he be sent an expression of sincere appreciation and thanks for his direction, guidance, and untiring efforts since the inception of the Associates. Mr. Swope continues as a member of the Executive Committee and was named Chairman of the Associates.

A quorum being present, Mr. Noel B. McLean was elected President and Mr. John A. Gifford was re-elected Secretary. In addition to those members serving, the following were elected to the Executive Committee: Mr. Charles F. Adams, Jr., Dr. Benjamin H. Alton, Mr. Pomeroy Day, Mr. Frank Pace, Jr.

A change in the By-laws was discussed to provide a new class of membership open to yacht clubs, fishing clubs and other organizations having an interest in the sea. After a poll with members of the Executive Committee who were not present during the meeting the amendment was approved.

NEW CORPORATE ASSOCIATES

Since our last issue of OCEANUS, the following have joined the Corporate Associates:

Moran Towing and Transportation Co, Inc., New York, N. Y.
National Lead Company, New York, N. Y.
Nutrilite Products, Inc., Buena Park, California.

Food Productivity Of The Ocean

By Harden F. Taylor

What is the total productivity of the sea? Methods based on oxygen production and on the rate of uptake of carbon 14 have shown radically different results as to the magnitude of production in the sea. Here a novel approach, based on catch statistics, is discussed.

The ultimate measure of the productivity of living matter in the sea as on land is the amount of carbon fixed by photosynthesis per square meter, or mile, per year. Various ingenious methods have been devised and applied for measuring this production — fine silk net tows, micro counting, weighing and analysis of the plant cells, measurement of the amount of chlorophyll therein, checking by the decrease in CO^2, nitrogen, phosphorus, etc., and increase in oxygen, all of which occur in the water as a result of plant growth. These results have been checked by analysis of definite quantities of water confined in light and dark bottles.

After extensive research of his own, Dr. Gordon Riley summarized from the scientific literature the state of knowledge of vegetable productivity of both land and sea. His summary conclusions were that the general average carbon fixation for the entire land area of the earth, including deserts, etc., is 160 metric tons per square kilometer per year; that of the sea 340 tons per year, both subject to a wide range of possible error. Since the land covers about 29% of the surface of the earth and the sea 71%, the total photosynthesis of the earth per years is 20 billion tons of carbon fixation on the land area and 126 billion tons at sea.

Even though the total basic production at sea appears to be more than six times as great as it is on land, the sea now provides less than one per cent of man's food, and none of the fiber, lumber, fuels, etc., which are derived from present and past production of vegetable matter on land. With the human population increasing at the rate of 20 to 25 million a year, and probably doubling or more in the next century, what can be expected from the sea?

Comparisons

In such attempts as have been made to compare possible production on land and sea, it has been made to appear that much if not all the advantage in greater basic productivity at sea is lost in one way or another, and the net result is a pessimistic view of what the sea can ever provide.

On land, man can use vegetables directly as food; a part is consumed by animals and thereby converted or transformed into their own body tissues as meat, eggs, milk, etc. A considerable part of land vegetation is in useless stems, roots, leaves, etc.

Eat or Be Eaten

Usually, on land, only one step of food transformation from vegetable to useful animal is involved, with efficiency varying from five to twenty-five per cent, i.e., of each one hundred units of vegetable food energy consumed, in the case of cattle, sheep, and poultry about five parts or 5% is recoverable as edible meat; in swine, around twenty per cent is recoverable; eggs represent about seven per cent of the food consumed, and milk about fifteen per cent. But these are all warm animals which dissipate as body heat the energy of a large part of the diet merely to keep their bodies warmer than their surroundings; in man about two-thirds of the food goes to keeping our bodies warm.

At sea, however, the microscopic vegetation is not now directly consumed by man, and quite probably never will be. It is contained in a prodigious amount of water, and would be excessively expensive to collect even if it were acceptable as food, which it is not. The individual plants are so small that they must be converted by the natural processes of step by step food transformation into larger animals, each step having its own percentage of efficiency.

It has been asserted that at sea a greater part of these minute vegetable cells is frittered away by sedimentation and decomposition, by the prodigal wastefulness of the many steps of transformation that must intervene between microscopic plants and fish that are large enough to be useful, and also, by the gross inefficiency at each step, so that the outlook is dim for any very large increase in the food supply from the sea.

Food Steps

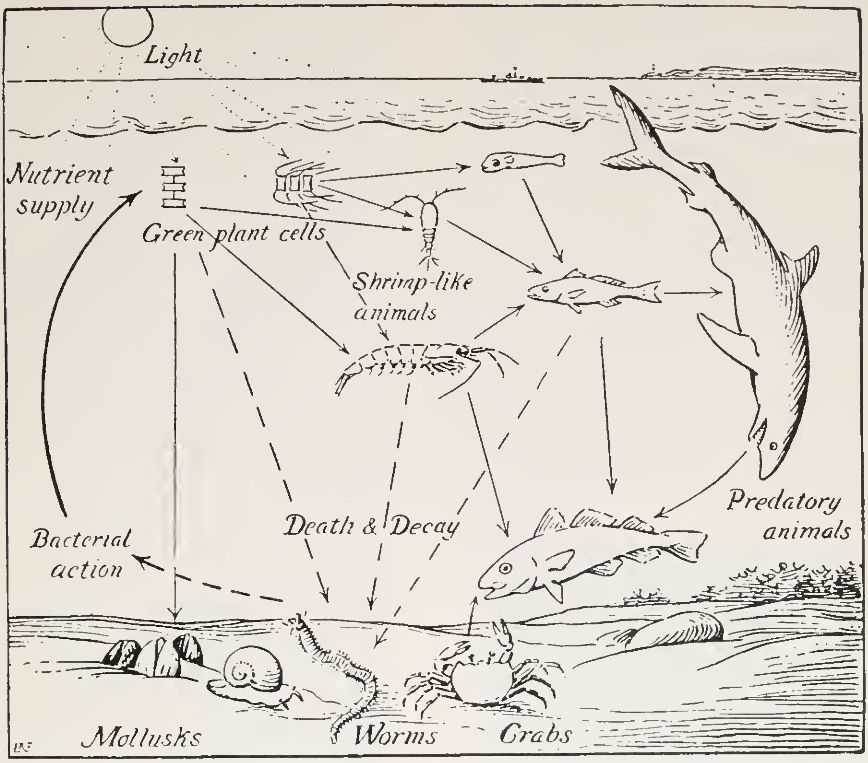
These steps of food transformation have usually been assumed to be four or five in number, and the efficiency about five or ten per cent at each step, i.e., five to ten pounds of animal growth for each one hundred

pounds of food eaten. By such estimates, or assumptions, it has been reckoned by one scientist that 10,000 pounds of diatoms is equal to 1,000 pounds of copepods which produces 100 pounds of herring leading to 10 pounds of mackerel, then to 1 pound of tuna and finally 1/10th pound of man, or a net of 100,000 to 1. A reckoning by another authority of the overall efficiency of the system as codfish production was 1/10,000 to 1/20,000 of the ultimate plankton from which the codfish was derived. If such computations even approximate the true situation, the yield of useful fish must be small indeed. For if the total carbon fixation is, according to Riley's summary, 340 metric tons per square kilometer (972 U. S. tons per square mile) per year, the carbon contained in the useful fish could not be more than one ten thousandths as much, or about 200 pounds of carbon per square mile per year, even if all the basic vegetation goes to codfish. Expressed in more familiar terms, it would be ⅓ pound of carbon or, at eight pounds of fish to one pound of carbon, about three pounds of fish per acre per year.

For comparison with these quantities, it is possible to apply a certain check from the actual fish production. The North Atlantic Ocean produces a fourth of the world commercial catch of fish. For our purpose it is the equivalent of a confined lake, since *all* the great Atlantic fisheries for herring, cod, mackerel, redfish, haddock, whiting, etc., are contained therein north of latitude 40° N. (New Jersey to Portugal). The official statistics of the commercial catch are available. The area of the 90° spherical triangle on base latitude 40° N, the meridians 15° E. (Kattegat) and 75° W. (New York), the apex at the North Pole, less the land area therein, is 5,967,000 square miles. The product from this area in 1950 was 6,480,274 U. S. tons of fish, or 1.087 tons of fish per square mile of water.

How much carbon did the fish contain? A compilation from the literature of 148 analyses (by different chemists) of 267 specimens of 64 species of common commercial salt-water and anadromous fishes from the North Atlantic and Pacific gives an average of 18.45% protein and 4.14% fat, or, at 52% carbon in protein and 77% in fat, the carbon content was 12.782% of the wet fish, or .1389 tons, or 278 pounds of carbon, per square mile. This is more than the maximum amount of 200 pounds of

600 Pounds of Tuna Equal to 60,000 Pounds of Herring?



After: George Clarke.

The life cycle of the sea. Green plants, microscopic in size grow by photosynthesis in the surface layers of the sea, they are eaten by the zoo-plankton, small shrimplike creatures which in turn are eaten by bigger and bigger fish. As life dies, it is eaten and disintegrated through bacterial action, again releasing nutrients in solution to the sea water. The ocean plows and fertilizes itself.

carbon allowed by the estimate cited above which was based on ten per cent efficiency and four steps of conversion. At ten per cent efficiency, and only 3.85 steps of conversion, the fish actually caught would account for all the 972 tons (estimate cited above) of carbon fixed in the entire North Atlantic Ocean. Actually the fish came from only about one sixth of the total water area, or one million square miles.

Obviously, the productive mechanism at sea must somehow be much better than has been supposed, for the fish actually taken from only one sixth of the total area, without any allowance for all other animals not captured, contains more carbon than could be accounted for by the estimated carbon fixation of the whole area if the average number of steps from diatoms to fish is four and the efficiency of transformation at each step is

ten per cent. The synthesis of vegetable matter must be greater, or the efficiency of food transformation must be better, or the number of steps fewer, or some more favorable combination of possibly all three factors must prevail.

The authorities quoted assumed ten per cent efficiency, perhaps because the figure chosen lies in about the middle of the range of efficiencies for agricultural livestock (four to five per cent for cattle, etc., twenty per cent for swine), but livestock animals are warm blooded, while fish are cold. Such sparse

Setting a Seine Net

date as we have found in the literature indicates that in the larval and juveniles of fish, and also invertebrates, the efficiency of food transformation is as high as forty per cent, declining to fifteen or ten per cent in adults to we do not know what inefficiency in terminal old age.

How Many Steps?

The number of steps of transformation for any fish or species of fish need not be an exact whole number — indeed it never is unless by accident. The herring is said to eat copepods and copepods to eat diatoms, and therefore the herring is said to be two steps removed from vegetable plankton. The diet of the herring is far more complex than that. The diet of the copepods is not purely vegetarian. The herring also eat other shrimps, the euphausiids, in large numbers, and these in turn eat diatoms, but also a good deal of other assorted animals; the herring diet also contains the eggs of other animals which have eaten a great variety of things, so that the calculation of the remoteness of any particular herring from the base would involve the remoteness of each item of its diet, which if not vegetarian in turn has its assortment, each item of which may in turn have still another assortment. The expression of remoteness of a fish from base therefore must be a statistical average of a great many other averages, in a tangled network of predators and prey. Undoubtedly most carnivorous fishes in their larval and juvenile stages are plankton consumers, and as they grow larger and older eat larger and older food which is more and more remote from base, so that, say, a larval cod may be 2.1 steps from the vegetable base, when scrod may be 3.2, market cod may be 3.8 and old cod five or six steps from base. Its efficiency is quite likely dying away too, from, say, forty per cent when larval to twenty-

five per cent when scrod to fifteen when marketable to maybe five per cent when large or old cod, but of this we know very little indeed.

We can here only illustrate the significance of these facts by an imaginary example: If a larval cod is at the second step of remoteness from the vegetable base and it and its food chain are twenty-five per cent efficient in metabolism, then each unit of carbon in its body could be accounted for by only seventeen units of carbon in the vegetable base; when it is in the third stage, and if the whole food chain is, for instance, fifteen per cent efficient each unit would call for 322 units at the base; if in the fourth stage and the chain ten per cent efficient, 10,870 units of carbon; and finally an old cod, if in the fifth state of remoteness from base and the chain as a whole is only five per cent efficient, would require 3,478,400 units of carbon in the vegetable base for each unit of carbon in its body. It seems to this writer unlikely that the codfish can be either so far from the base as this, or the whole chain so inefficient metabolically, but the illustration may serve to show that these two factors are the great determinants of the abundance of a species, and the yield of a fishery.

What we now take from the ocean is a mere trifle; the waters near the great markets now yield all the fish that can be sold and at costs far below those of agricultural livestock.

ABOUT THE AUTHOR

Dr. Harden F. Taylor. Rounded career combining fishery biology, technology at U. S. Bureau of Fisheries, Director of Research and later President Atlantic Coast Fisheries Co.; then Director Survey Marine Fisheries, University of North Carolina.

International Geophysical Year

Plans for oceanographic participation in the International Geophysical Year 1957-58 were discussed on September 8-14 at a meeting held in Brussels, Belgium. Our director, Dr. Edward H. Smith, Chairman of the Subcommittee on Oceanography of the Special Committee for the Geophysical Year, and Senior Oceanographer Columbus O'D. Iselin took part in the discussions.

During the IGY, scientists of many nations will conduct the most comprehensive study of the earth ever undertaken. Our environment, particularly the atmosphere and oceans affect the daily lives of all individuals, the transactions of commerce and industry and all communications.

It is expected that about forty vessels will participate in the oceanographic program which is divided into three main parts.

1. To obtain a better understanding of the short and long term changes in sea level which may provide an indication of weather trends, i.e. periods of gradual warming up of the entire world. Many of these observations will be made on islands in the ocean.

2. A study of the motions of the deep water in the sea, particularly in equatorial regions and polar approaches. A better knowledge of the vast exchanges of water between those regions is necessary if we are to make long range weather forecasts. Observations will be made by many ships including the ATLANTIS and the VEMA, of Columbia University's, Lamont Geological Laboratory, along two North-South lines reaching from the Arctic to Antarctica. A multiple ship operation will be made in a suitable area of these lines.

3. A multiple ship operation across the boundary of temperate and polar waters and possibly at the outflow of Mediterranean water in the North Atlantic.

It is obvious that such a grandiose program will be possible only by the pooling of facilities and personnel of many nations. This program will be discussed in detail in future issues of OCEANUS. However, considering the limitations imposed by size, we refer to the September issue of Scientific American which is devoted entirely to the IGY and also carries an article on the Circulation of the Oceans by Dr. Walter Munk of the Scripps Institution of Oceanography.

Around the conference table of the IGY Committee on Oceanography at Brussels, Admiral Smith is surrounded by delegates from Russia, Pakistan, Japan, Norway, Finland and Scotland. To his left is seated Dr. G. E. R. Deacon, Director of the British National Institute of Oceanography. Facing away from camera: Dr. Roger Revelle, Director of the Scripps Institution of Oceanography.

Atlantis To The Pacific

The Atlantis has set sail from Bermuda, after a month long investigation of ocean waves, and has departed for the Panama Canal to cross into the Pacific Ocean. This is rather an historic occasion as the ship has never left the Atlantic Ocean and adjacent seas since she was built at Copenhagen in 1930.

The purpose of the Pacific cruise, in charge of Mr. Henry C. Stetson, submarine geologist on our staff, is to investigate the submarine geology off the coasts of Peru and northern Chile. A unique geological feature exists in that area where a major mountain range, the Andes, follows the margin of a continental mass and adjoins an oceanic basin with many deep troughs lying close to shore. The Andes are a very young mountain chain and the situation is most interesting, as many similar relationships existed in the geologic past. Therefore, a comparision between the sediments being eroded and deposited into the present day Pacific and those of the major troughs in folds of the past should be most interesting and enlightening. Moreover, meager soundings existing off the coast of western South America indicate an area of pronounced reliefs. Our former concepts of the topography of the ocean bottom has changed completely during recent years, due to the advent of continuously recording echo-sounders, and the area will be thoroughly sounded with the aid of the Woods Hole echo-sounding recording system.

The cruise of the Atlantis should do much to fill in a gap in our knowledge of the floor of the ocean. There is no other oceanic area which affords a comparable opportunity to study the sedimentation of an inverted arch of a fold in the rock strata over a great distance. The high mountains and the deep troughs continue for many hundreds of miles. One of the main purposes of the cruise is to learn something of the principles which govern this type of sedimentation in order to interpret more precisely the history and stratigraphy of rocks laid down in similar environments of the past.

The ship will make a series of traverses, roughly to 300 miles off the coast, along Peru and northern Chile. Long cores of sediment samples will be taken with gravity type coring tubes together with short surface samples, while rock dredging will be attempted if suitable cliffs are found by echo-sounding. A complete study of the environment of the sedimentation will be obtained by water sampling with Nansen bottles, temperatures etc. The samples will be analyzed for salinity, dissolved oxygen, total phosphorus, dissolved inorganic phosphate, silicates and nitrates. As if all this were not enough, plankton samples will be taken with the Bumpus-Clarke sampler and a detailed study of the clays is to be made with an x-ray diffractometer. Trace elements in the water will receive attention and a thermal bottom probe will measure the flow of the earth's heat, to compare heat loss in the deep troughs with that on the adjacent submerged highlands. Some sediment cores will be deep frozen for later analyses.

The Atlantis (Captain W. Scott Bray, commanding) will spend a total of 62 days at sea from the time of sailing from the Panama Canal to the return there. A few days will be spent at Callao to celebrate Christmas. Mr. Stetson will join the vessel at Talara, Peru, together with Dr. Bernhard Kummel, Associate Professor of Geology at Harvard, Dr. Fisher, Chief geologist of the International Petroleum Comp. and Lieut. Cdr. Jose' Baranderian, Peruvian Navy, a well known oceanographer.

Dr. John M. Zeigler and Wm. D. Athearn of this Institution will join the ship in the Canal Zone, while Herbert Small and Robert A. Lufburrow will come on board at Callao. Others to join are: Dr. Parker D. Trask of the University of California, Mr. David H. Frantz, Jr. of our staff and Senor Jose' Stuardo, Aide to the Director of the Chilean Biological Station.

To allow the ship to proceed directly from Bermuda, the PBY 6A (Captain Norman Gingrass) has made several flights to Bermuda to return the wave recording equipment and personnel from Mr. Farmer's cruise.

Currents and Tides

A collection of mollusks obtained by Mr. William C. Schroeder during the ATLANTIS 1938-39 Harvard-Havana Expedition was described recently by Dr. Gilbert L. Voss of the Marine Laboratory, University of Miami.

One genus and four species new to science were found in the collection. One of the new species was named for Dr. A. C. Redfield, Abralia redfieldi and another for the ATLANTIS, Heteroteuthis atlantis.

Mr. M. J. Tucker of the British National Institute of Oceanography arrived in September to supervise the installation of a shipborne wave recorder developed by him. Mr. Tucker is presently on board the ATLANTIS for a wave measuring cruise in Bermudean waters. Mr. Harlow G. Farmer, Jr., Research Associate in Hydraulics, is chief scientist during the cruise.

First mate Arthur D. Colburn, Jr. of the ATLANTIS and Barbara C. Atwood of Dr. J. B. Hersey's group were married in September. This brings the number of WHOI marriages to about 35 or 40.

Forty-five papers were read during a Conference on the Physics of Clouds and Precipitation Particles held September 7-10 at the Institution. About 65 scientists from the U. S., Canada, Japan and Mexico attended the meetings, sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center and by the Office of Naval Research under the auspices of the American Geophysical Union of the National Academy of Sciences - National Research Council.

The PBY 6A made an arduous two months flight around the Carribean Sea to make observations of the earth's magnetic field with the aid of an airborne magnetometer. Mr. Maurice J. Davidson of Columbia University was scientist on board the flight piloted by Captain Norman Gingrass.

At a recent meeting held at Michigan State University, Dr. Alfred C. Redfield was elected President of the American Society of Limnology and Oceanography. Dr. Bostwick H. Ketchum was re-elected Secretary-Treasurer at the same meeting.

I heard the waves crashing upon the shore
To windward, to windward forevermore . . .

Captain Arvid Karlson has sailed away. With his sudden departure on Tuesday, October 19, the Institution has lost a valuable member. In accordance with Captain Karlson's wishes, his ashes will be carried out to the sea, which was his home for 50 years.

The term seaman is often loosely applied to anyone going to sea. There are but few, regardless of rank, of whom it may be said: "He was a real seaman." Captain Karlson belonged to that vast disappearing race of men of whom we generally think as clipper ship or whaling captains. Born in Vetlanda, Sweden, he left home at the age of 14 to sail on square riggers, until the age of steam caught up with him. Never being communicative, we know but little of Captain Karlson's days on oil tankers during the war days, but he cannot have been at home on their bridges. A man of few words, but those well chosen, his remarks became legendary during his life and will long continue to be so. Captain Karlson came to the Institution just ten years ago and sailed for many years as first mate on the R. V. Atlantis under Captain Adrian K. Lane, until receiving command of the R. V. Caryn. His years of care of the Atlantis show unto this day, and it is largely due to Karlson's efforts "to keep up ship," that the vessel is still able to work and work hard.

Unexcelled in celestial navigation, the stars were his closest friends. Let those of us who look at them, remember him. Fair winds, Skipper . . . . J. H.

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